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RESEARCH MEMORANDUM

MODEL DITCHING INVESTIGATION OF A JET TRANSPORT AIRPLANE WITH VARIOUS ENGINE INSTALLATIONS

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NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS

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SUMMARY

The ditching characteristics of a jet transport airplane with various engine installations were investigated in Langley tank no. 2. A dynamic model was used to determine the probable ditching behavior in calm water and the best ditching procedure. Various conditions of damage, engine installations, landing attitude, and speed were investigated. Data were obtained from visual observations, acceleration records, and motion pictures.

It was concluded that a low wing jet transport with any of the engine arrangements tested should be ditched at a nose-high attitude with the landing flaps down. The various engine configurations made no great differences in the overall ditching performance. The maximum longitudinal and the maximum normal acceleration may each be from 3g to 5g. Some of the engine nacelles will probably be torn away and the fuselage bottom will most likely be damaged enough to cause rapid flooding.

INTRODUCTION

An investigation of a model of a typical jet transport airplane with various engine configurations was made to observe the ditching behavior and to determine the safest procedure for making an emergency water landing. The ditching characteristics of these configurations were of general interest inasmuch as there is a current trend toward the use of large swept-wing multiengine airplanes. Four different engine installations were investigated with the model. Three arrangements were investigated only briefly, but a more detailed investigation was made with the strut-pod installation. (A three-view drawing of an airplane with a strut-pod engine installation is shown in fig. 1.) The investigation was made in calm water at the Langley tank no. 2 monorail.

APPARATUS AND PROCEDURE

Description of Model

The 0.043-scale model of a jet transport airplane with various engine arrangements shown in figure 2 was used in the investigation. The model was constructed of balsa wood and spruce, and was covered with silk to provide a durable water-resistant finish. Internal ballast was used to obtain scale weight and moments of inertia. The model had a wing span of 5.59 feet and an overall length of 5.50 feet.

The landing flaps were installed so that they could be held in the down position at approximately scale strength. In order to accomplish this, a calibrated string was fastened between each flap fitting and a corresponding wing fitting so that water loads within ±10 percent of the ultimate design load (3,000-pound full-scale normal load applied near the trailing edge of a flap) would cause the string to break. When the scale-strength connections failed, the flaps rotated to the retracted position.

The strut-pod engine nacelles were installed at approximately scale strength, in a manner similar to that described for the landing flaps. Each nacelle strut had a parting line near the nacelle; the strut and the nacelle were connected with a calibrated string which failed within ±10 percent of the ultimate drag load (40,000 pounds, full scale). When the scale-strength connections failed, the nacelles became detached from the model. The other three engine installations were made with the engines rigidly attached to the model.

The model was constructed so that a portion of the fuselage bottom could be replaced with an approximately scale-strength section. The assumed full-scale ultimate strength of the fuselage bottom surface was approximately 10 pounds per square inch. The scale-strength bottoms were constructed of cardboard bulkheads and balsa-wood stringers and were covered with aluminum foil. A bottom is shown installed on the model in figure 3. Scale-strength bottoms were used to indicate the location and extent of damage that might occur in a ditching. The scale-strength fuselage bottoms were applied only with the strut-pod engine installation, but all engine installations were tested with the model having a simulated damage bottom as shown in figure 4. The simulated damage bottom was used to expedite the test program because the use of the scale-strength bottoms indicated the portion of the fuselage bottom that would be damaged and the behavior resulting with the simulated damage bottom was not appreciably different from that with the scale-strength bottom.

Test Methods and Equipment

Tests were made at the Langley tank no. 2 monorail (fig. 5). The model was ditched by catapulting into the air to permit a free glide onto the water. The model left the launching carriage at scale speed and the desired landing attitude with the control surfaces set so that the attitude did not change appreciably in flight. The behavior was recorded by a motion-picture camera and from visual observations. Accelerations were recorded by a two-component time-history accelerometer installed in the forward portion of the passenger compartment. The longitudinal decelerations and normal accelerations were measured parallel and perpendicular, respectively, to the fuselage reference line. (See fig. 1.) The accelerometer components had natural frequencies of 73 cycles per second and were damped to about 65 percent of critical damping. The reading accuracy of the instrument was $\pm\frac{1}{4}$g.

Test Conditions

The model was investigated at the following test conditions (all values are full scale):

Weight.- A gross weight of 130,000 pounds was used for the investigation.

Moments of inertia.- The model was ballasted to approximate the following values of moments of inertia:

Roll, slug-ft^2	1,700,000
Pitch, slug-ft^2	2,000,000
Yaw, slug-ft^2	3,500,000

Center of gravity.- The center of gravity was located at 26 percent of the mean aerodynamic chord and 60.7 inches above the fuselage bottom surface.

Landing attitude.- Three landing attitudes were used in the strut-pod engine installation investigation: 12° (near lift-curve stall angle), 9° (intermediate), and 6° (low). The other three engine installations were tested only at the 12° landing attitude. The attitudes were measured with respect to the fuselage reference line.

Flaps.- Tests were made with the landing flaps in the up and in the down 50° positions. The down flaps were attached at scale strength.

Landing speed.- The landing speeds are listed in table I. The model was airborne when launched and within ±5 knots of these speeds.

Landing gear.- All tests simulated ditchings with the landing gear retracted.

Fuselage conditions.- The model was tested with the following fuselage conditions:

(a) No damage simulated, figure 2

(b) Scale-strength fuselage bottom installed, figure 3 (strut-pod installation only)

(c) Simulated damage to the aft fuselage bottom, figure 4

Engine installation.- The model was tested with the following engine configurations:

(a) Strut-pod engines, figures 2(a), (b), and (c)

(b) Wing-root engines, figure 2(d)

(c) Under-fuselage engines, figure 2(e)

(d) Side-fuselage engines, figure 2(f)

RESULTS AND DISCUSSION

A summary of the results of the investigation is presented in tables I and II; all values are full scale. The notations used in the tables are defined as follows:

Ran smoothly - the model made no apparent oscillation about any axis and gradually settled into the water as the forward velocity decreased.

Skipped - the model made an undulating motion about the transverse axis in which the model cleared the water completely.

Ran deeply - the model moved through the water partially submerged and exhibited a tendency to dive although the attitude did not change appreciably.

Trimmed down - the attitude of the model decreased shortly after contact with the water.

Trimmed up - the attitude of the model increased.

Porpoised - the model made an undulating motion about the transverse axis in which some part of the model remained in contact with the water.

General Behavior

No simulated damage.- The undamaged model with the strut-pod engine configuration and the flaps up ran smoothly at the 12° and 9° attitudes, and skipped and ran deeply at the 6° attitude. The maximum longitudinal deceleration was about $2\frac{1}{2}$g and the maximum normal acceleration was about 4g in landing runs of about 890 feet at the 12° attitude, and about 1,100 feet at the 9° and 6° attitudes.

Ditchings with the flaps down resulted in smooth runs at the three attitudes tested. The maximum longitudinal deceleration was about $2\frac{1}{2}$g and the maximum normal acceleration was about $3\frac{1}{2}$g in landing runs of about 640 feet at the 12° attitude, 850 feet at the 9° attitude, and 1,040 feet at the 6° attitude.

The undamaged model with any of the other three engine installations (tested only at the 12° landing attitudes) resulted in landing runs of about 900 feet with flaps up. The maximum longitudinal deceleration varied from $1\frac{1}{2}$g to 3g and the maximum normal acceleration was about $3\frac{1}{2}$g. The model generally ran smoothly with all engine installations except the under-fuselage configuration with which the model skipped and ran deeply. Ditchings with the flaps down generally resulted in smooth runs with a maximum longitudinal deceleration of about 2g and a maximum normal acceleration of about $3\frac{1}{2}$g in landing runs of about 650 feet. Data for each configuration are presented in tabular form in table II.

Simulated damage.- Further investigation made with the various nacelle installations and simulated damage to the aft fuselage shown in figure 4 resulted in considerable differences in behavior. The model with the strut-pod engine installation shown in figure 2(a) trimmed down, trimmed up, and ran smoothly when ditched with the flaps up or down. With flaps up, the maximum longitudinal deceleration was about 4g and the maximum normal acceleration was about 3g in landing runs of about 845 feet. Ditchings with the flaps down resulted in landing runs of about 610 feet, a maximum longitudinal deceleration of about $3\frac{1}{2}$g, and a maximum normal acceleration of about 3g.

The model with the wing-root engine installation shown in figure 2(d) porpoised and ran smoothly with the flaps up; the maximum longitudinal deceleration was about 4g and the maximum normal acceleration was about $3\frac{1}{2}$g in landing runs of about 930 feet. Ditchings with the flaps down resulted in landing runs of about 535 feet, a maximum longitudinal deceleration of about $3\frac{1}{2}$g, and a maximum normal acceleration of about $2\frac{1}{2}$g.

The model with the under-fuselage engine installation shown in figure 2(e) skipped and ran deeply with the flaps up. The maximum longitudinal deceleration was about $5\frac{1}{2}$g and the maximum normal acceleration was about $4\frac{1}{2}$g in landing runs of about 630 feet. The model ran smoothly and ran deeply in ditchings with the flaps down and showed a maximum longitudinal deceleration of about $3\frac{1}{2}$g and a maximum normal acceleration of $2\frac{1}{2}$g in landing runs of about 465 feet.

The model with the side-fuselage engine installation shown in figure 2(f) trimmed down, trimmed up, and ran smoothly when ditched with the flaps up or down. With flaps up, the maximum longitudinal deceleration was about $3\frac{1}{2}$g and the maximum normal acceleration was about $4\frac{1}{2}$g in landing runs of about 675 feet. Flaps-down ditchings had a maximum longitudinal deceleration of about 3g and a maximum normal acceleration of about $5\frac{1}{2}$g in landing runs of about 600 feet.

Scale-strength fuselage bottom.- When the model with the strut-pod engine configuration was ditched with scale-strength fuselage bottom installed, it trimmed down immediately after contact with the water, then trimmed up and ran smoothly for the remainder of the run. This behavior was characteristic for ditchings at all three landing attitudes tested with the flaps either up or down. The changes in attitude during typical ditchings with the flaps down are shown in figure 6. Also shown in figure 6 are typical time-history plots of normal acceleration and longitudinal deceleration. Figure 7 shows sequence photographs of a typical ditching run at the 12° landing attitude.

Effect of Damage

Considerable damage occurred during all ditchings with scale-strength fuselage bottoms installed. This damage caused the model to

trim down shortly after contact, and the landing runs were shorter and the decelerations higher than when no damage was present. Typical damage to the scale-strength portion of the fuselage bottom is shown in figure 8. Ditchings at the 12° landing attitude for the condition with the flaps down resulted in less damage than for the other conditions tested. The simulated damage condition (fig. 4) resulted in the same general type of behavior as that resulting from the scale-strength bottom even though the decelerations were somewhat lower and the landing runs slightly longer.

Effect of Flaps

When the model was ditched at the various landing attitudes with the flaps down, the scale-strength flap connections failed shortly after the model contacted the water and the flaps rotated to the retracted position. There was no noticeable difference in general behavior when the model was ditched with the flaps up or down, although ditchings with the flaps up resulted in somewhat more damage to the fuselage bottom due to the higher speeds necessary for flaps-up landings. Ditchings with the flaps up generally resulted in higher maximum longitudinal decelerations and normal accelerations than with the flaps down.

Effect of Landing Attitudes and Speed

A decrease in the landing attitude and the accompanying increase in speed contributed to more damage and slightly higher maximum decelerations at most conditions. Therefore, the nose-high attitude of about 12° is considered best for a ditching.

Effect of Engine Installation

Ditchings with the strut-pod engine installation with scale-strength strut attachments resulted in two or three nacelles' being torn away most of the time. There was no appreciable difference in behavior whether the nacelles were torn away or not. However, in tests made with the engine nacelles removed, the runs were longer and smoother than when the nacelles were attached.

The wing-root engine installation affected the ditching behavior only when the conditions were such that the model settled deeply into the water. The additional bottom area furnished by the nacelle bottoms produced more lift causing the model to trim up, thus resulting in a porpoising motion. As the forward speed decreased the porpoising ceased and the model ran smoothly.

When the model was ditched with the under-fuselage engine installation, the engine cluster contacted the water first. During the first portion of the ditching run the engine cluster served as a planing surface. Near the end of the run the model settled in rather deeply and came to an abrupt stop. The model had a slight skipping or bouncing tendency but in general ran fairly smoothly for the greater portion of the run.

During a ditching with the side-fuselage engine installation the nacelle pods caused considerable spray as they entered the water. This configuration tended to have the highest normal accelerations of those tested; however, the longitudinal decelerations were about the same as for the other configurations.

There were slight differences in behavior for the various engine installations but the behaviors were never violent and there was no indication that any difference in ditching procedure would be required because of the engine installation.

CONCLUSIONS

From the results of the calm-water ditching investigation of a dynamic model of a jet transport with various engine arrangements, the following conclusions were drawn:

1. A jet transport with any of the engine arrangements tested should be ditched at a nose-high attitude with the landing flaps down.

2. The various engine configurations made no great differences in the overall ditching performance.

3. The maximum longitudinal deceleration and the maximum normal acceleration may each be from 3g to 5g.

4. Some of the engine nacelles will probably be torn away and the fuselage bottom will most likely be damaged enough to cause rapid flooding.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., June 22, 1956.

TABLE I

SUMMARY OF RESULTS OF DITCHING INVESTIGATION OF A SCALE MODEL OF A JET TRANSPORT AIRPLANE WITH STRUT-POD ENGINE INSTALLATION

[Gross weight, 130,000 lb; static normal accelerometer reading, 1g; all values are full scale.]

Landing attitude, deg	Flap setting, deg	Landing speed, knots	Maximum longitudinal deceleration, g	Maximum normal acceleration, g	Length of landing run, ft	Motions of model
Undamaged model with scale-strength nacelle struts						
12	50	100	2	3½	640	Ran smoothly
12	0	119	1½	3½	890	Ran smoothly
9	50	104	1½	3½	850	Ran smoothly
9	0	127	2½	3½	1,090	Ran smoothly
6	50	113	2½	3	1,040	Ran smoothly
6	0	146	2½	4	1,100	Skipped, ran deeply
Model with scale-strength fuselage bottom and scale-strength nacelle struts						
12	50	100	5	4½	470	Trimmed down, trimmed up, ran smoothly
12	0	119	6½	5½	480	Trimmed down, trimmed up, ran smoothly
9	50	104	5	5	420	Trimmed down, trimmed up, ran smoothly
9	0	127	5½	6	500	Trimmed down, trimmed up, ran smoothly
6	50	113	6	6	450	Trimmed down, trimmed up, ran smoothly
6	0	146	6½	5½	700	Trimmed down, ran deeply

TABLE II

SUMMARY OF RESULTS OF DITCHING INVESTIGATION OF A SCALE MODEL OF A JET TRANSPORT AIRPLANE WITH VARIOUS ENGINE CONFIGURATIONS

[Gross weight, 130,000 lb; static normal accelerometer reading, 1g; landing attitude, 12°; all values are full scale.]

Engine configuration	Flap setting, deg	Landing speed, knots	Maximum longitudinal deceleration, g	Maximum normal acceleration, g	Length of landing run, ft	Motions of model
Undamaged model						
Strut-pod	50	100	2	3½	640	Ran smoothly
	0	119	1½	3½	890	Ran smoothly
Wing-root	50	100			600	Ran smoothly
Under-fuselage	50	100	2	2	660	Ran smoothly, ran deeply
	0	119	3	4	1,000	Skipped, ran deeply
Side-fuselage	50	100	2	2½	775	Ran smoothly
	0	119	2	3½	925	Trimmed up, ran smoothly
Simulated damage to aft fuselage bottom						
Strut-pod	50	100	3½	3	610	Trimmed down, trimmed up, ran smoothly
	0	119	4	3	845	Trimmed down, trimmed up, ran smoothly
Wing-root	50	100	3½	2½	535	Porpoised, ran smoothly
	0	119	4	3½	930	Porpoised, ran smoothly
Under-fuselage	50	100	3½	2½	465	Ran smoothly, ran deeply
	0	119	5½	4½	630	Skipped, ran deeply
Side-fuselage	50	100	3	5½	600	Trimmed down, trimmed up, ran smoothly
	0	119	3½	4½	675	Trimmed down, trimmed up, ran smoothly

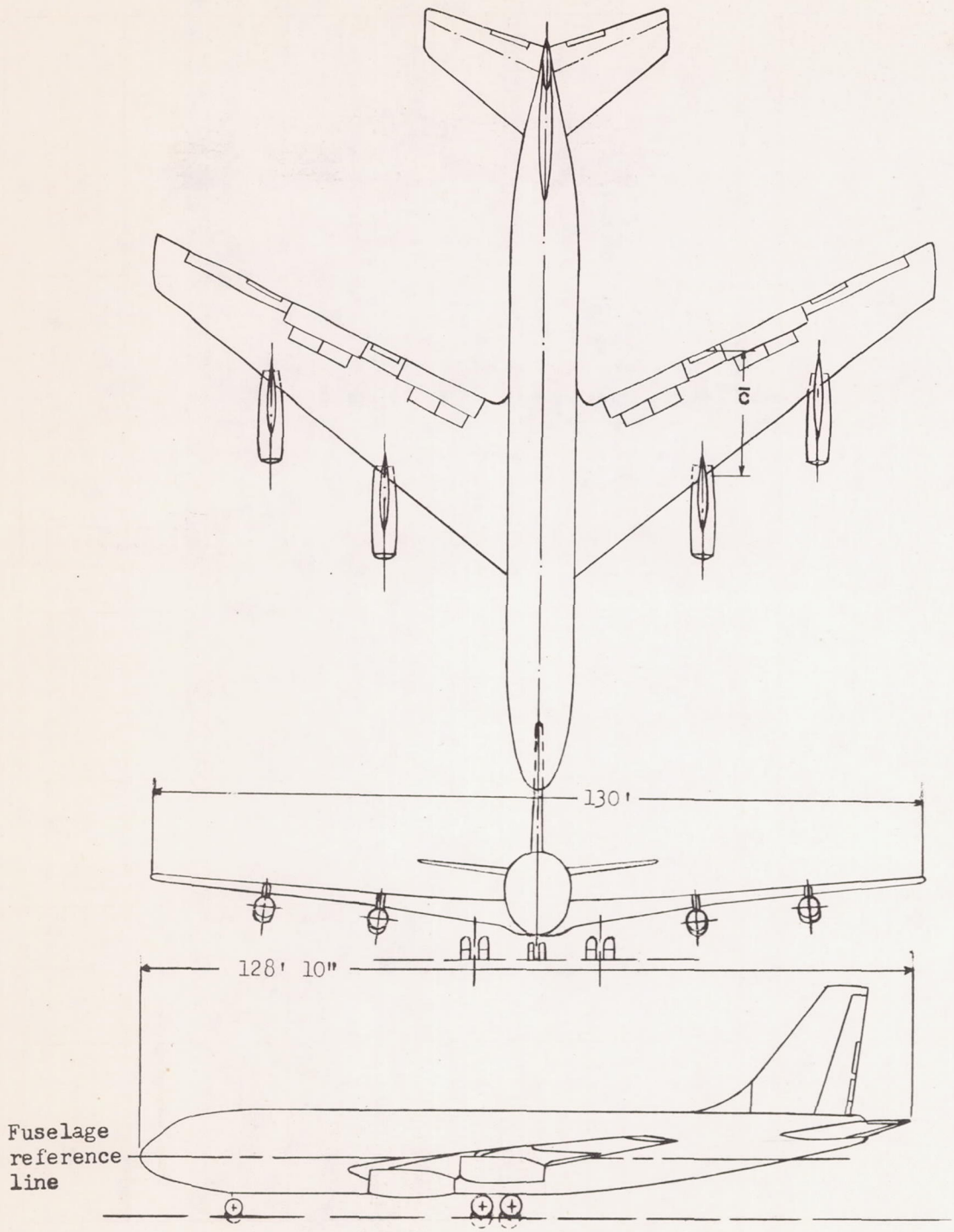
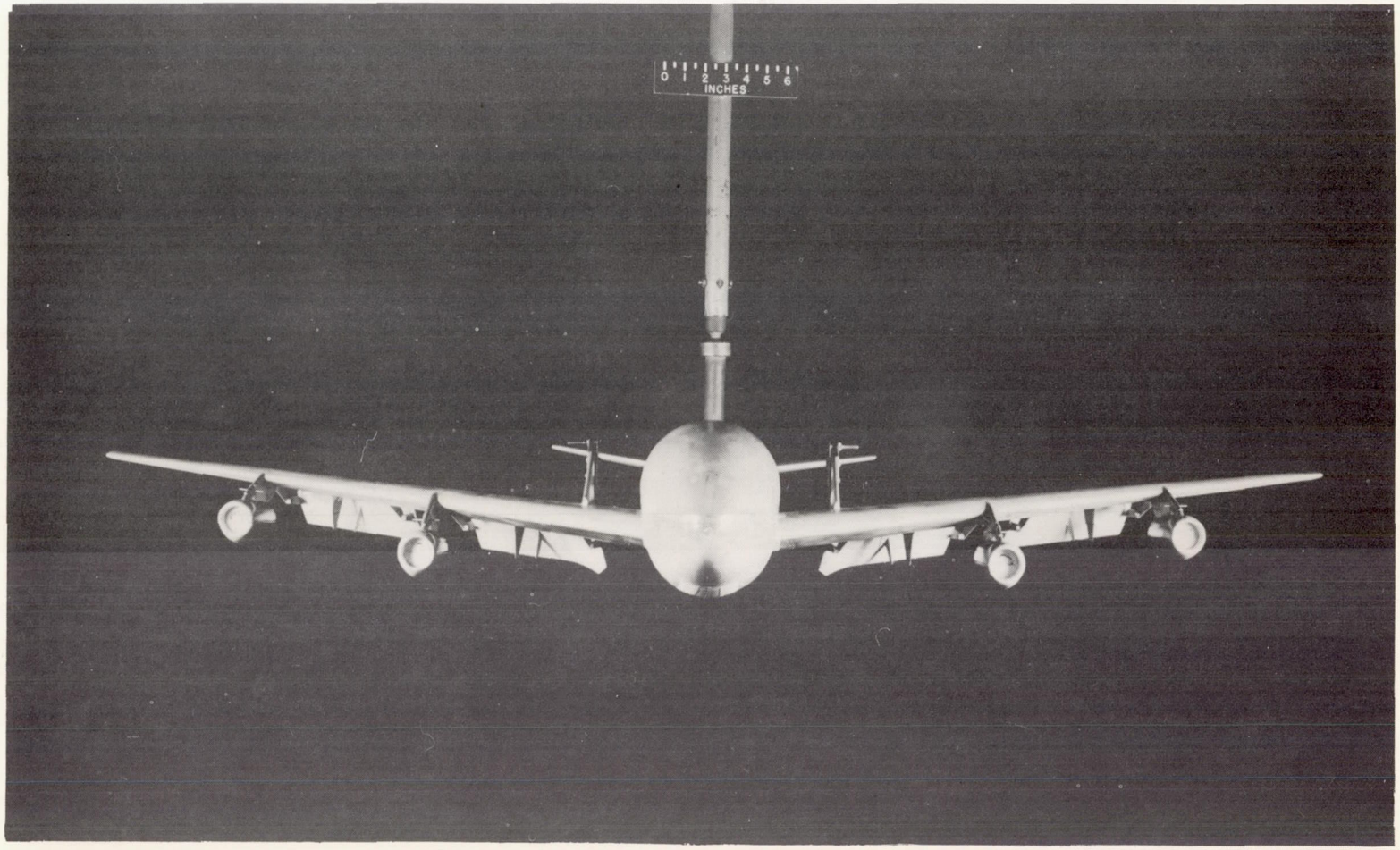


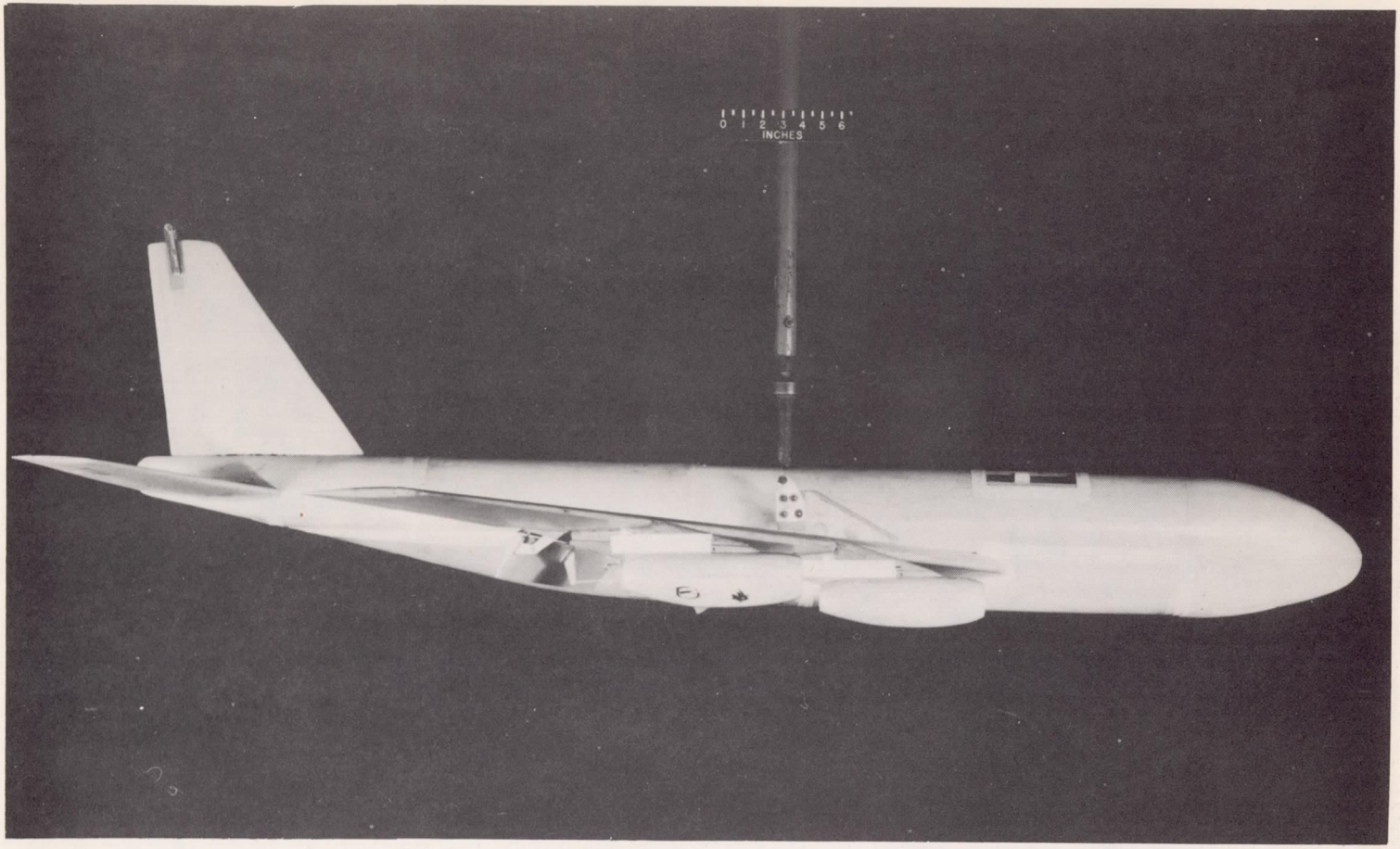
Figure 1.- Three-view drawing of a jet transport airplane with strut-pod engine installation.



L-85060

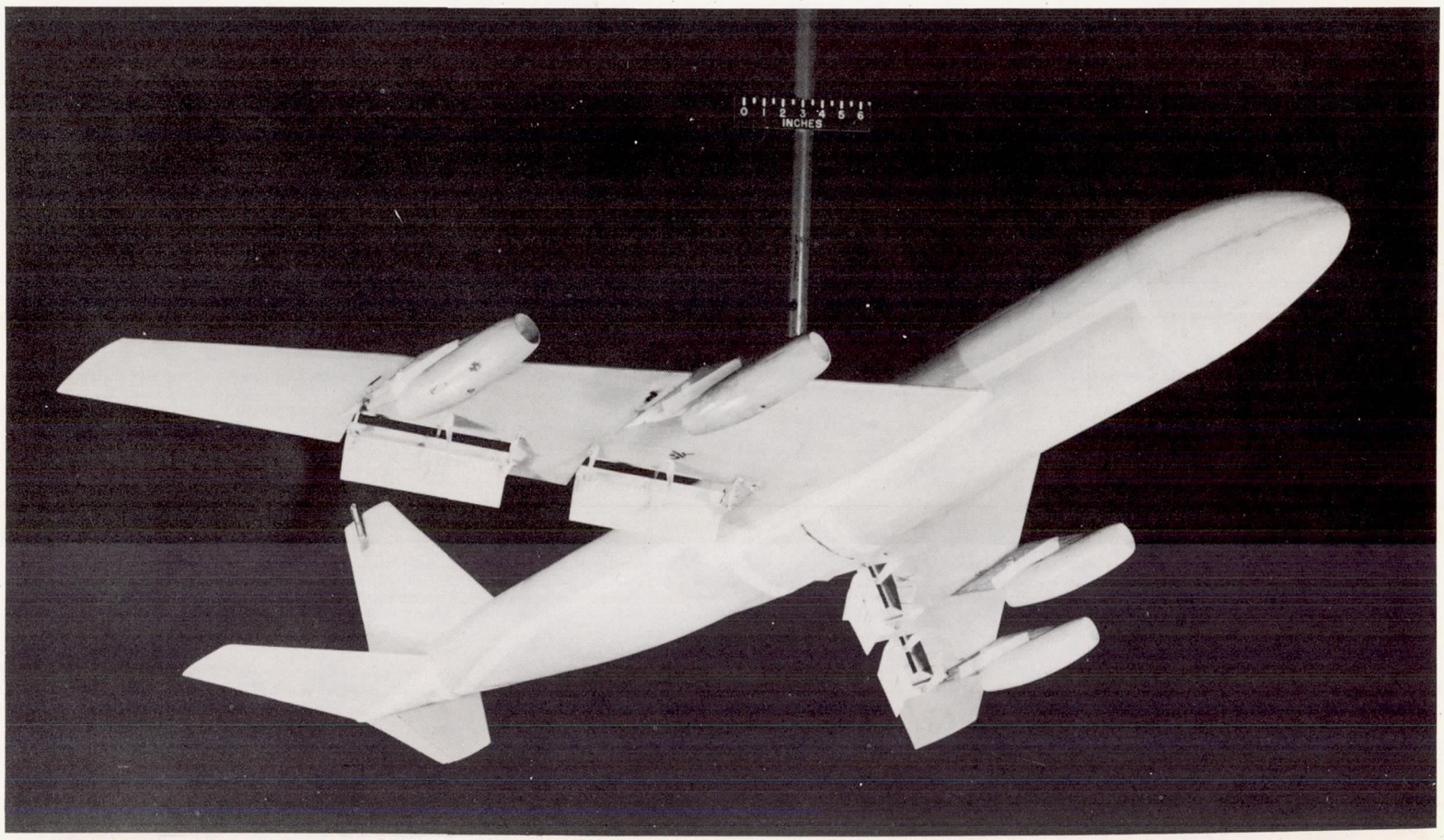
(a) Strut-pod engine installation, front view.

Figure 2.- Ditching model of jet transport airplane with various engine installations.



(b) Strut-pod engine installation, side view. L-85059

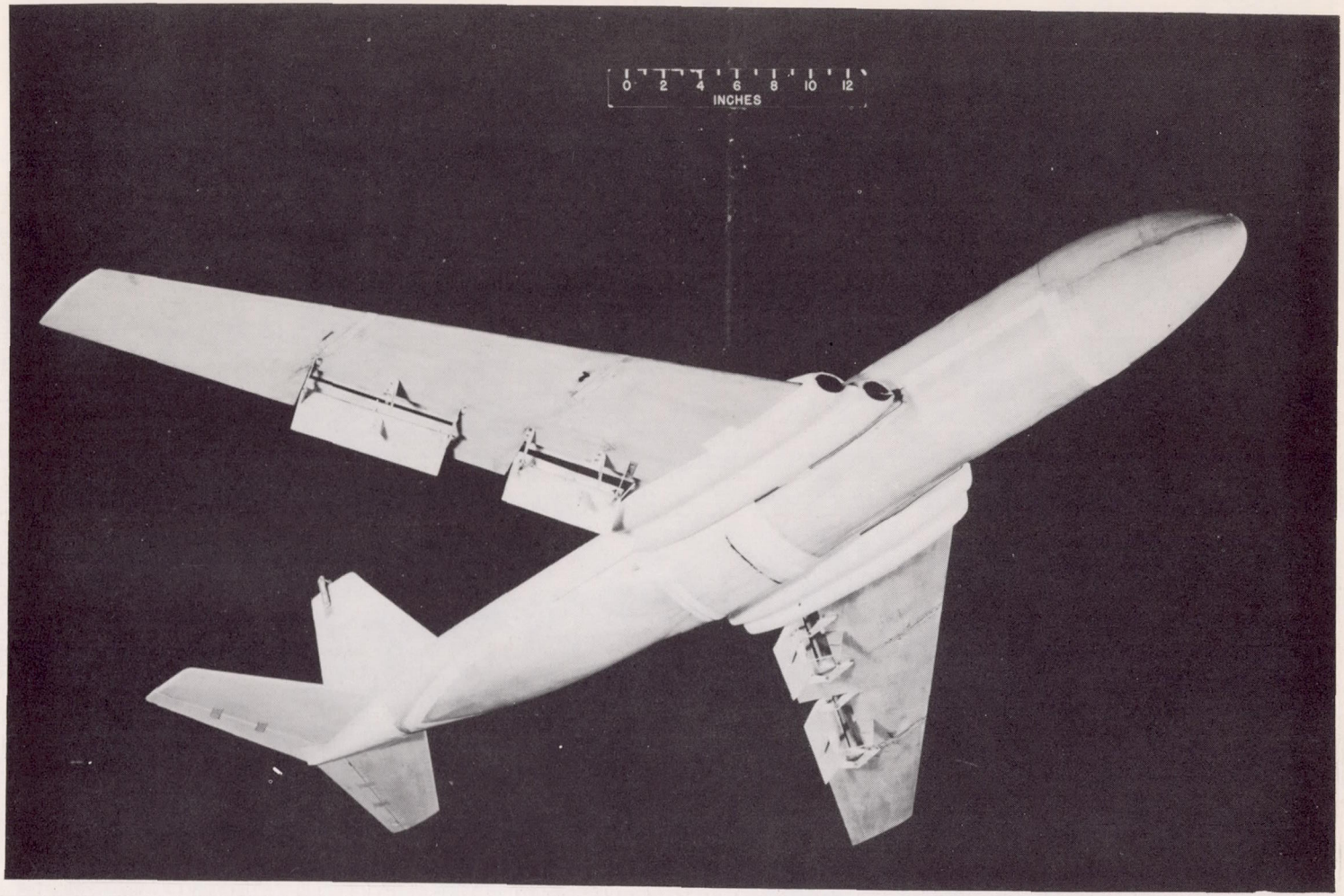
Figure 2.- Continued.



L-85061

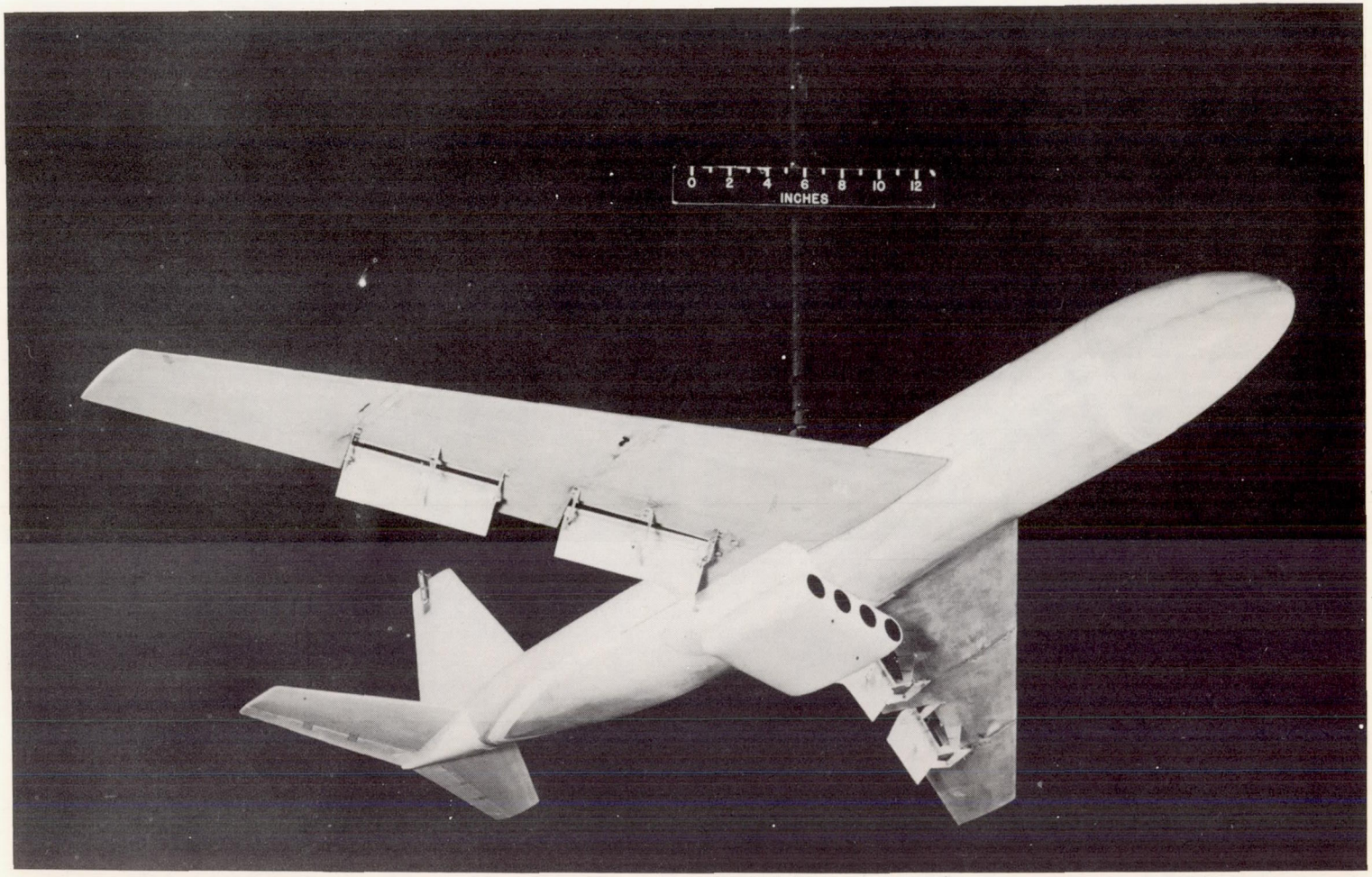
(c) Strut-pod engine installation, three-quarter bottom view.

Figure 2.- Continued.



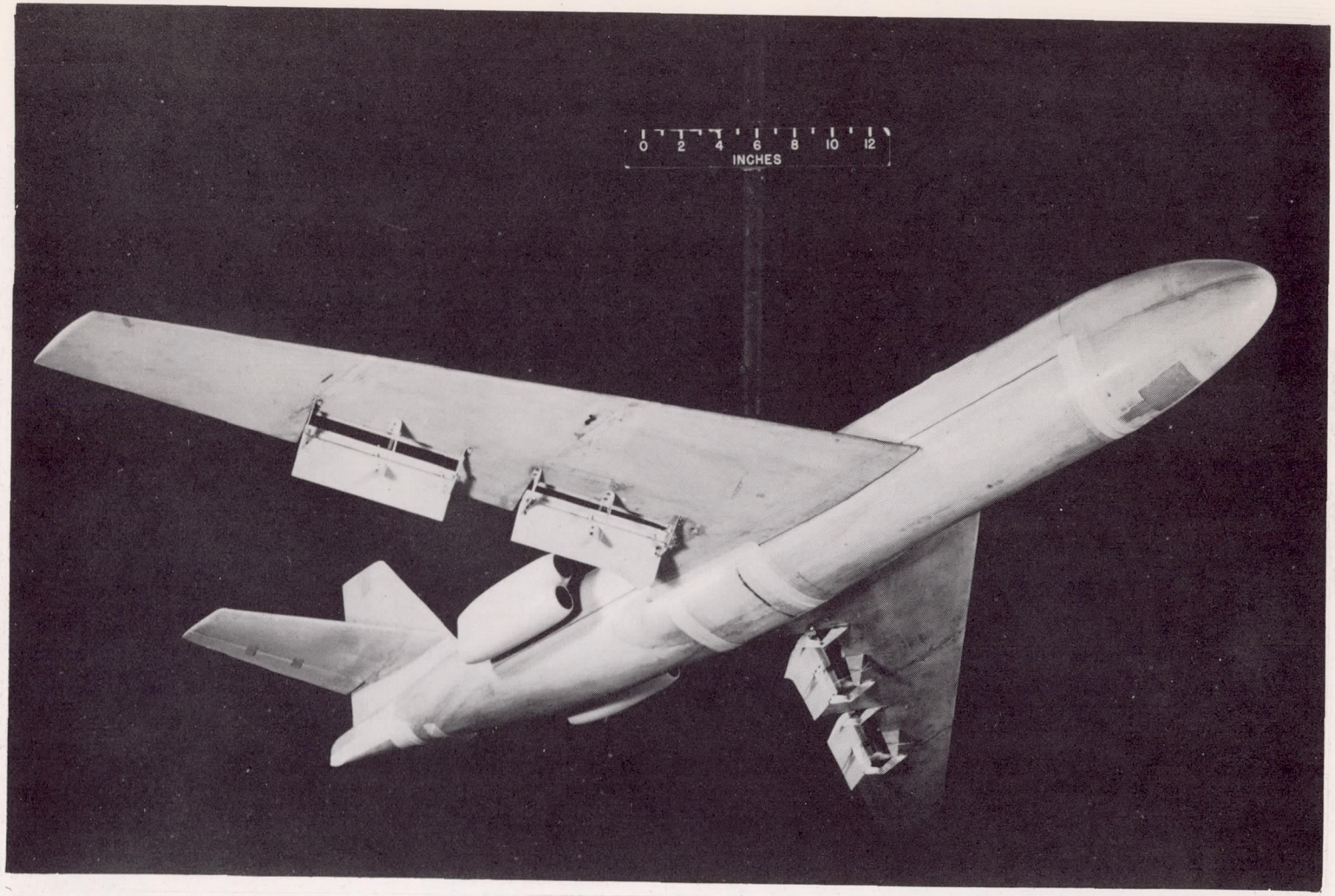
(d) Wing-root engine installation. L-86271

Figure 2.- Continued.



(e) Under-fuselage engine installation. L-86268

Figure 2.- Continued.



(f) Side-fuselage engine installation. L-86554

Figure 2.- Concluded.

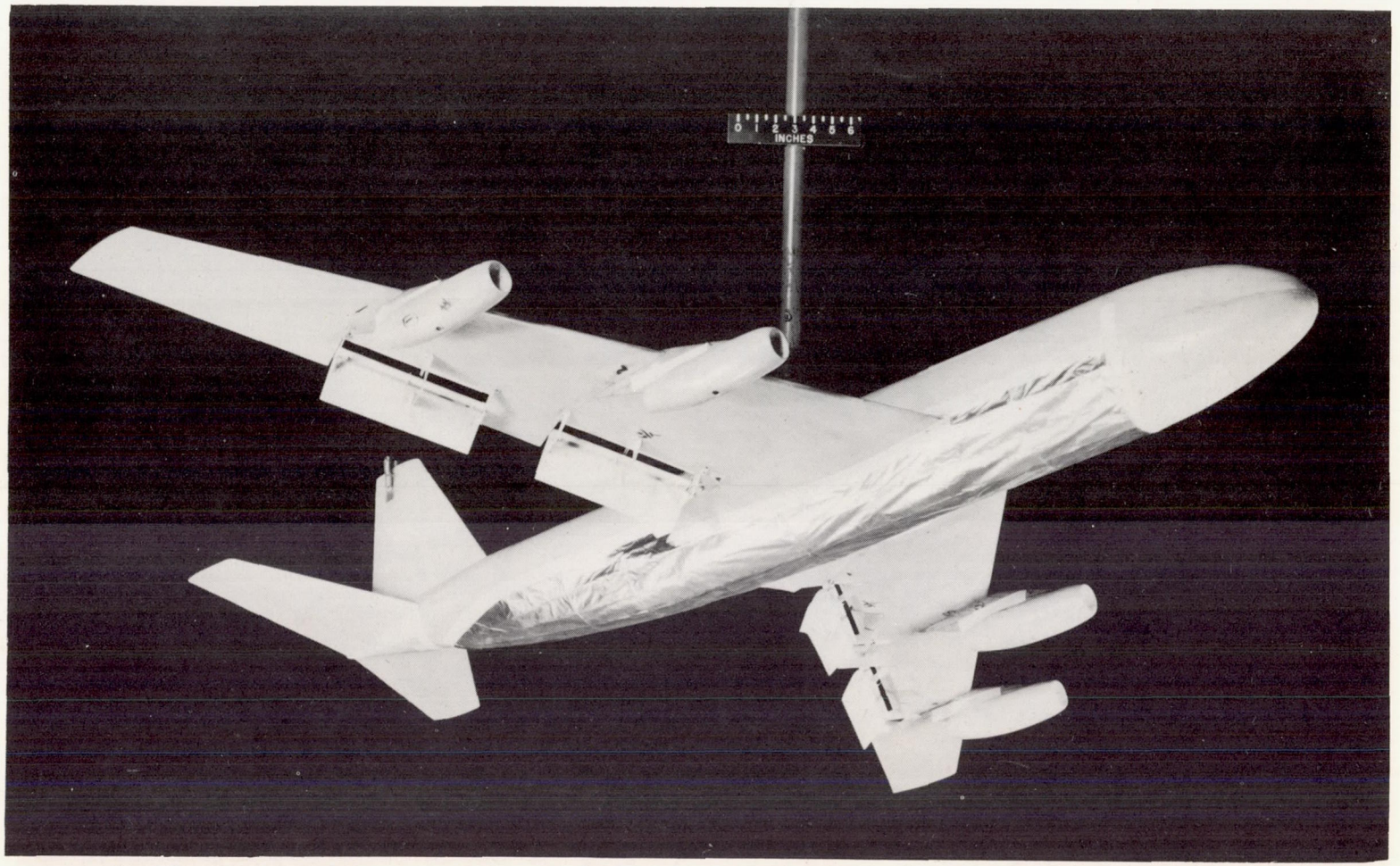


Figure 3.- Model with scale-strength fuselage bottom section. L-85062

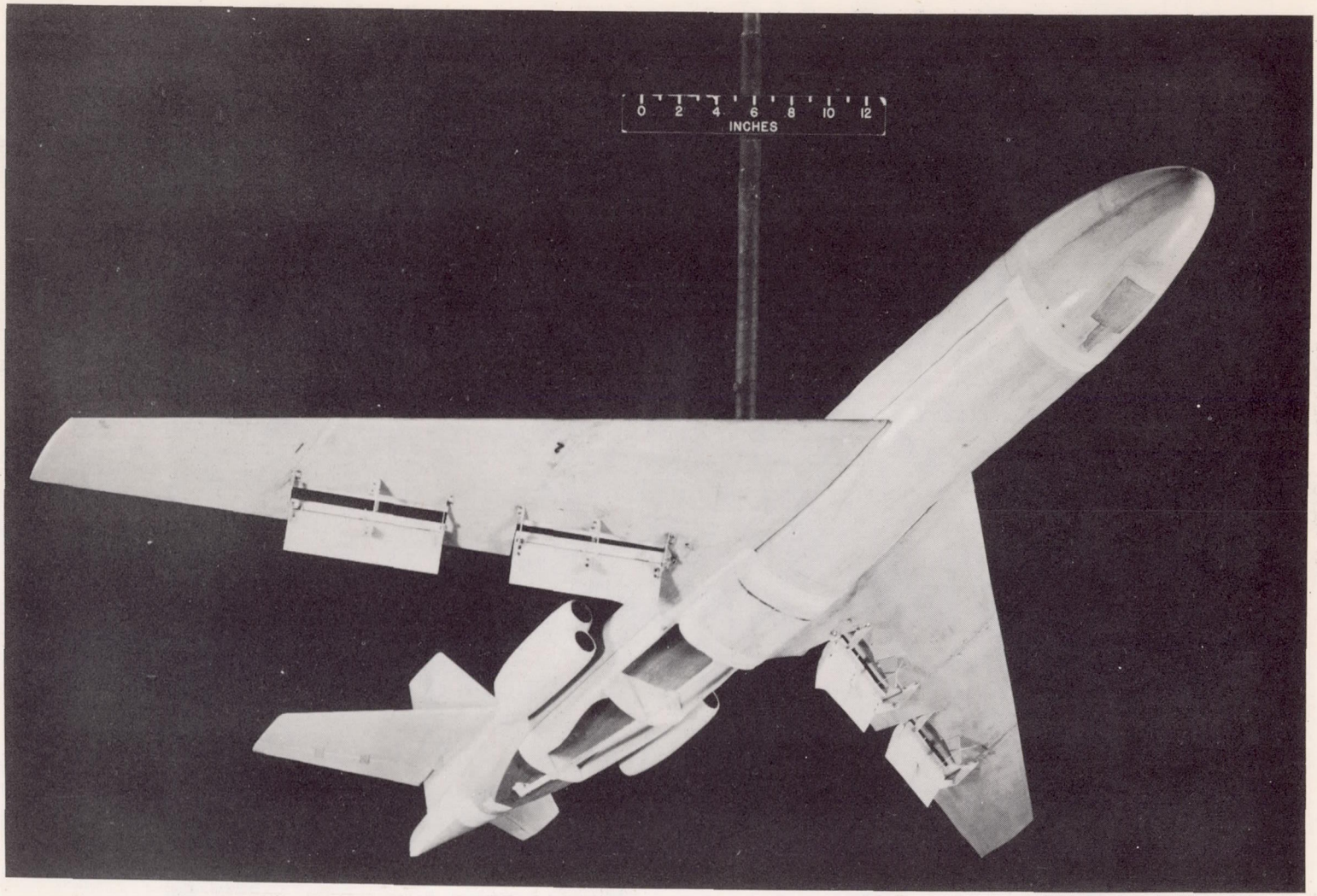
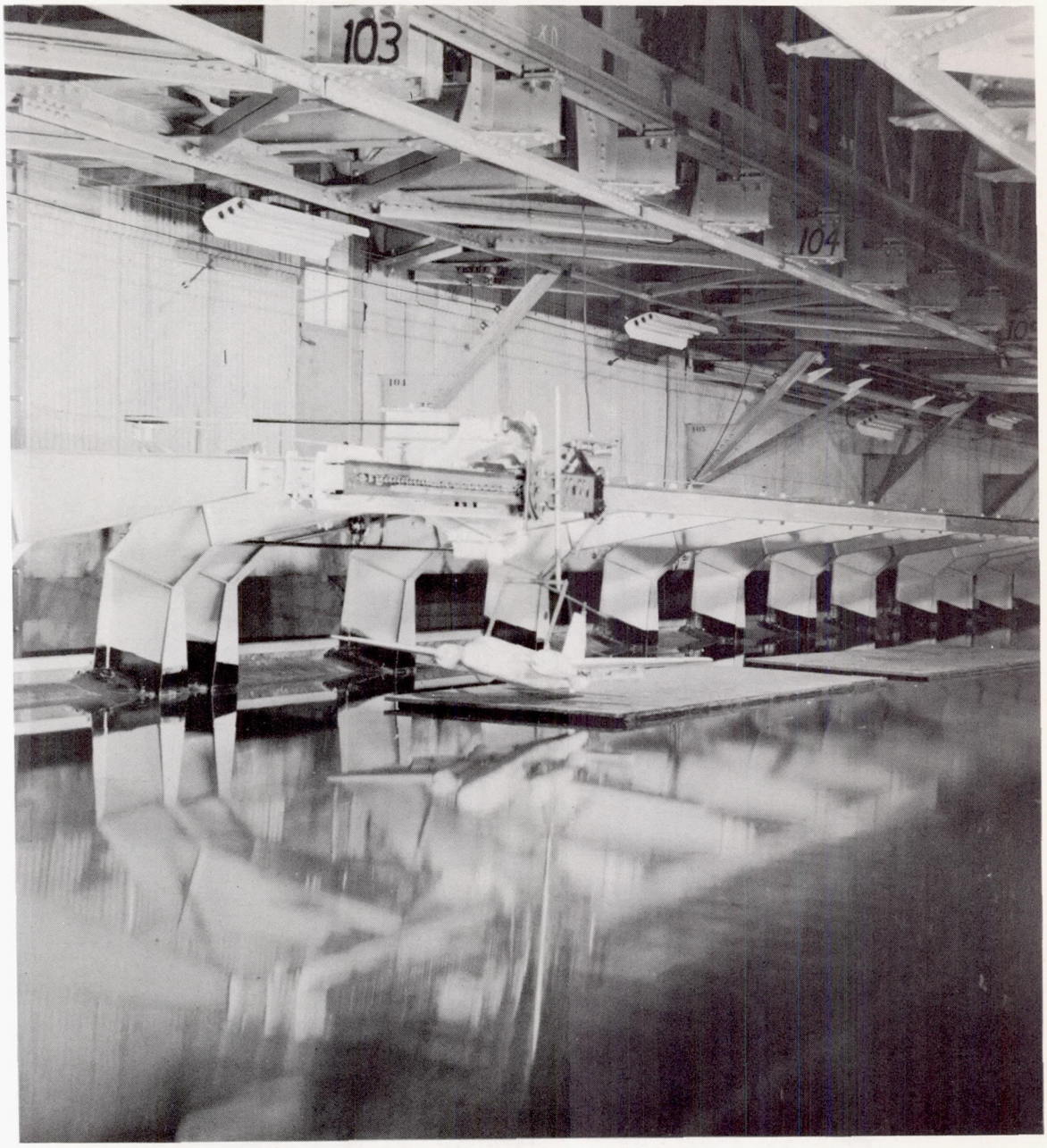
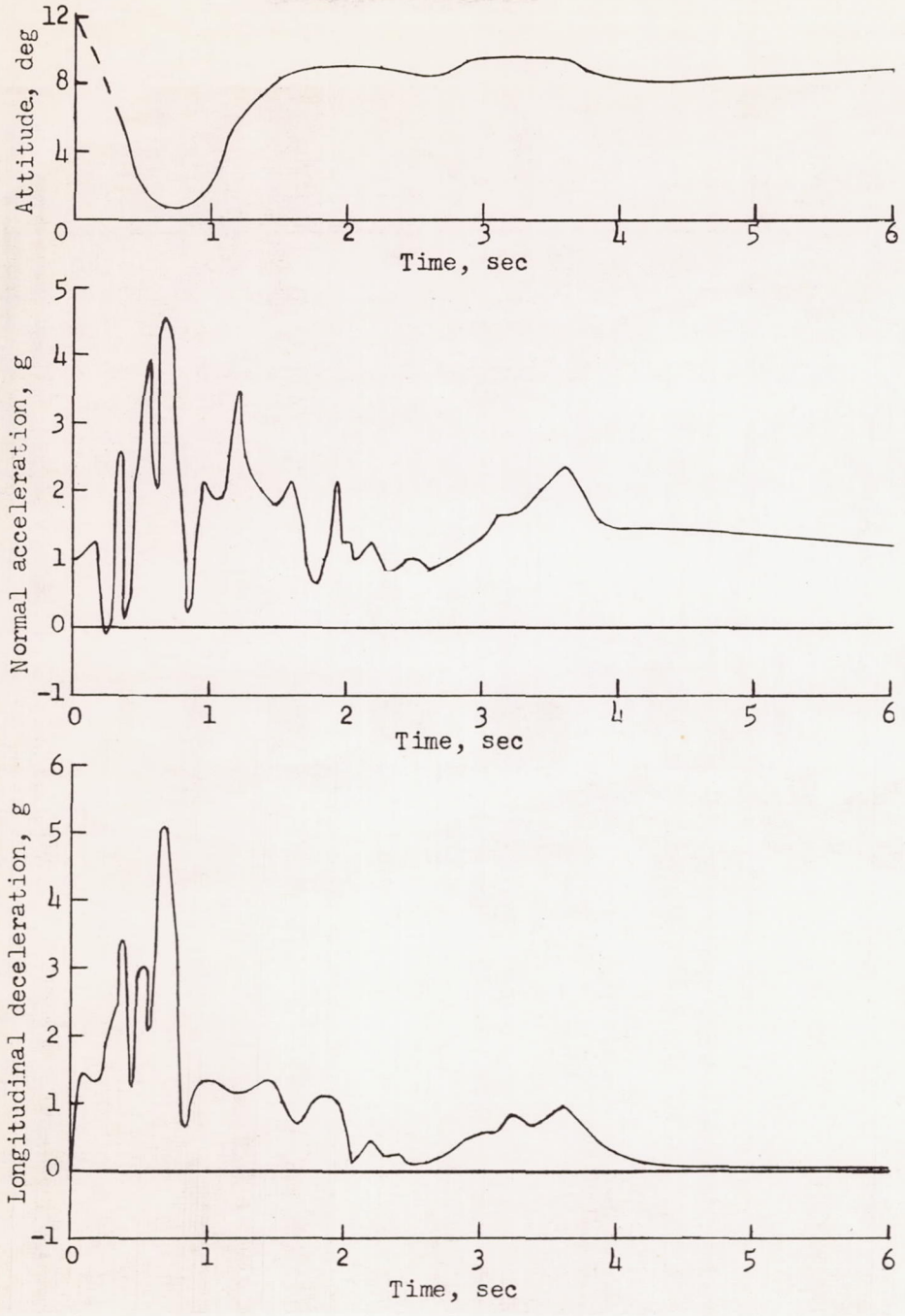


Figure 4.- Model with simulated damage to aft fuselage. L-86553



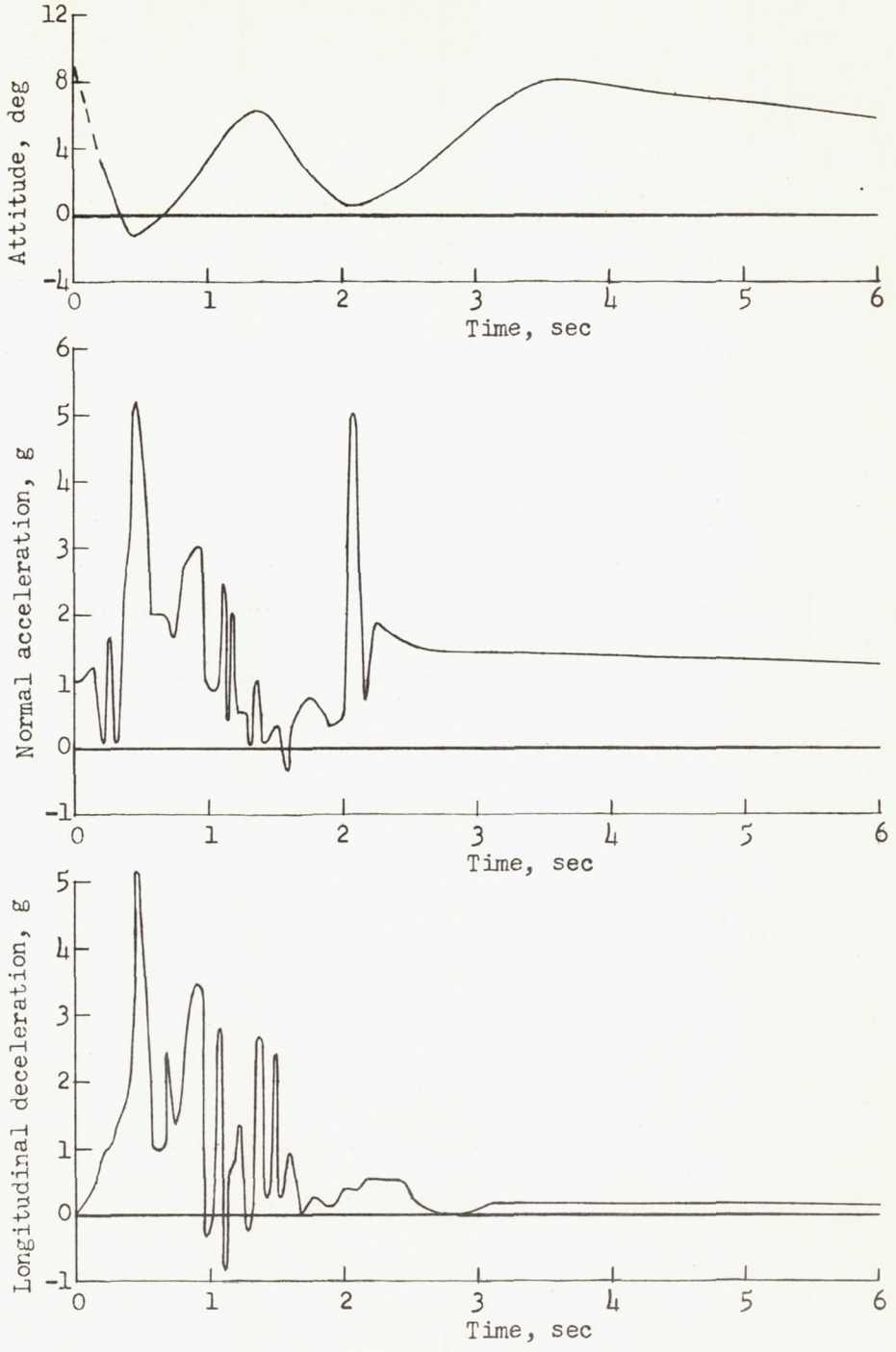
L-49333

Figure 5.- The Langley tank no. 2 monorail with a model attached.



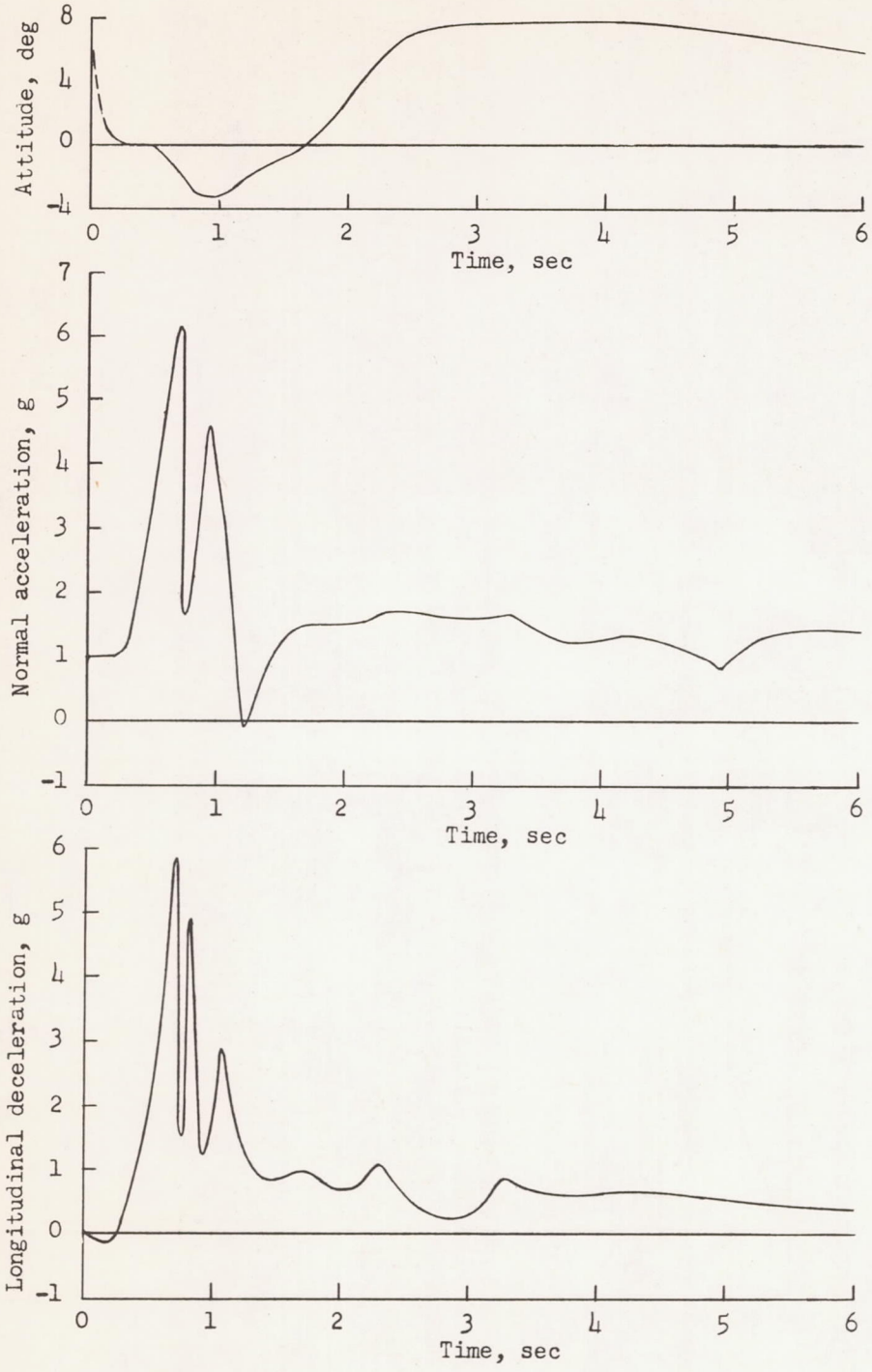
(a) Landing attitude, 12°; landing speed, 100 knots.

Figure 6.- Time history plots with scale-strength fuselage bottom and scale-strength struts on the strut-pod engine installation. Flaps down; values are full scale.



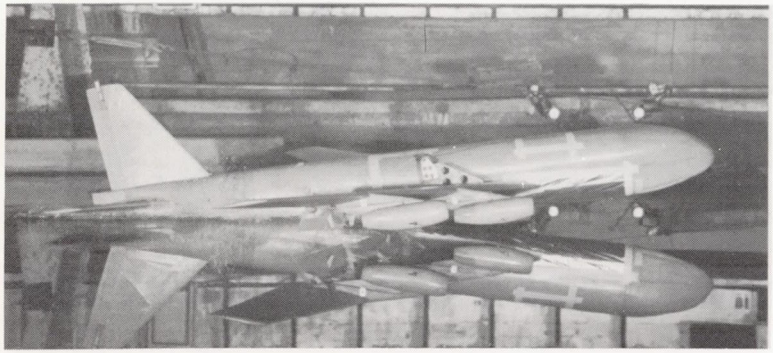
(b) Landing attitude, 9°; landing speed, 104 knots.

Figure 6.- Continued.

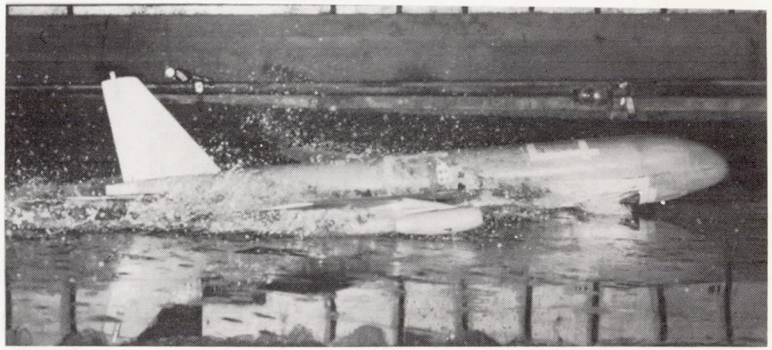


(c) Landing attitude, 6°; landing speed, 113 knots.

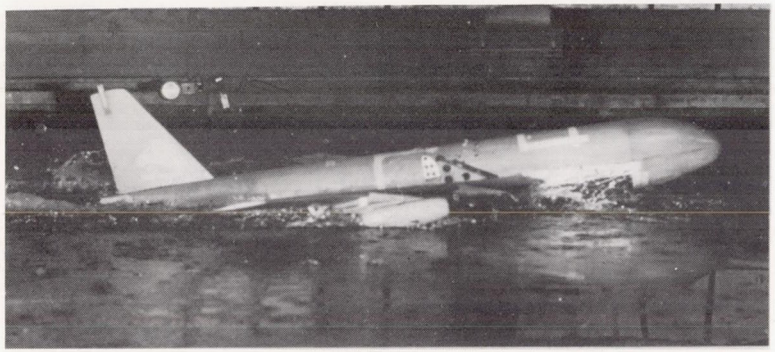
Figure 6.- Concluded.



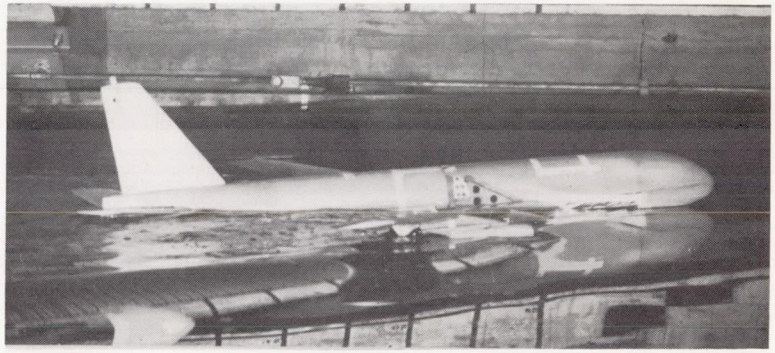
Near contact



180 feet



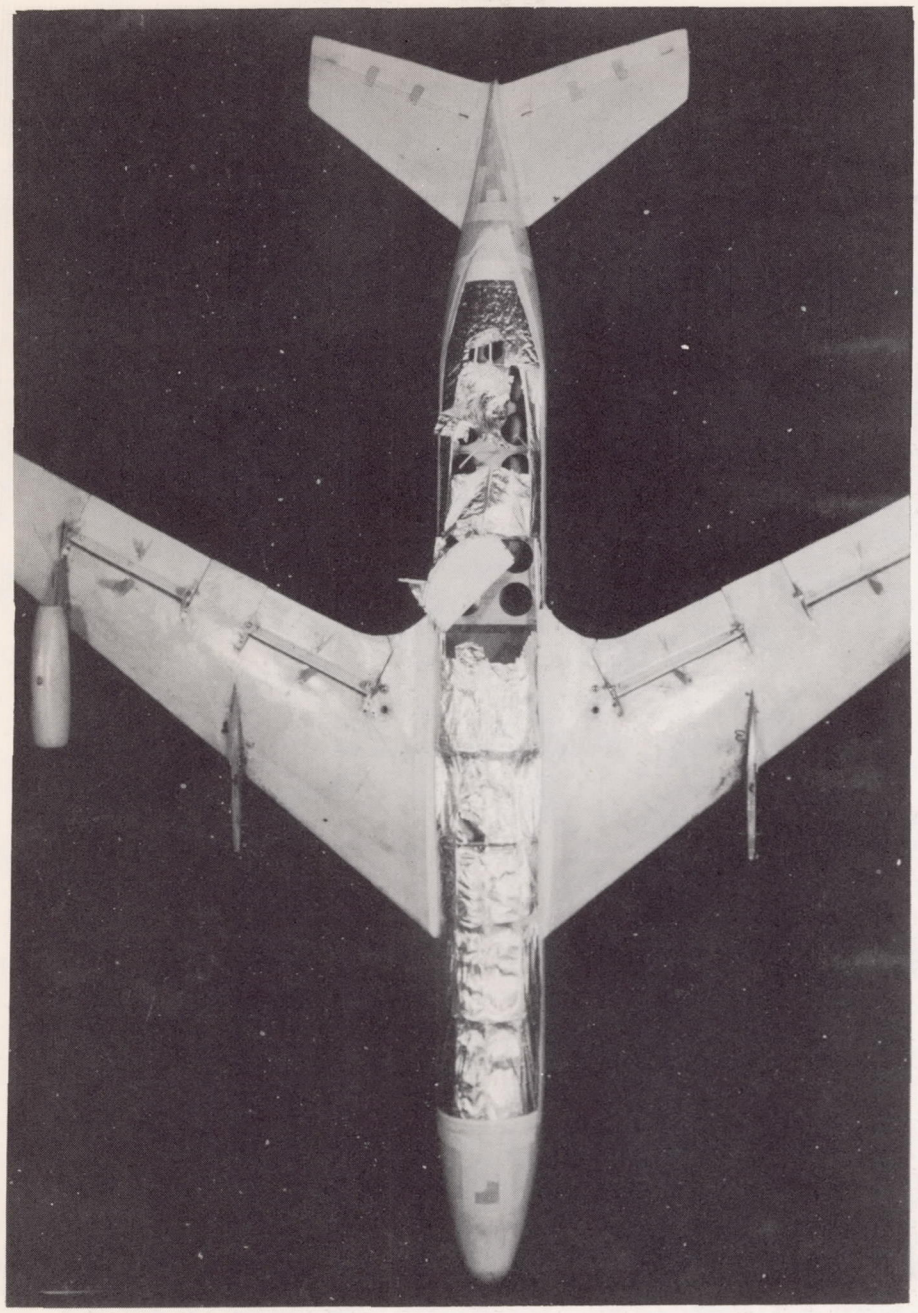
350 feet



470 feet

L-90558

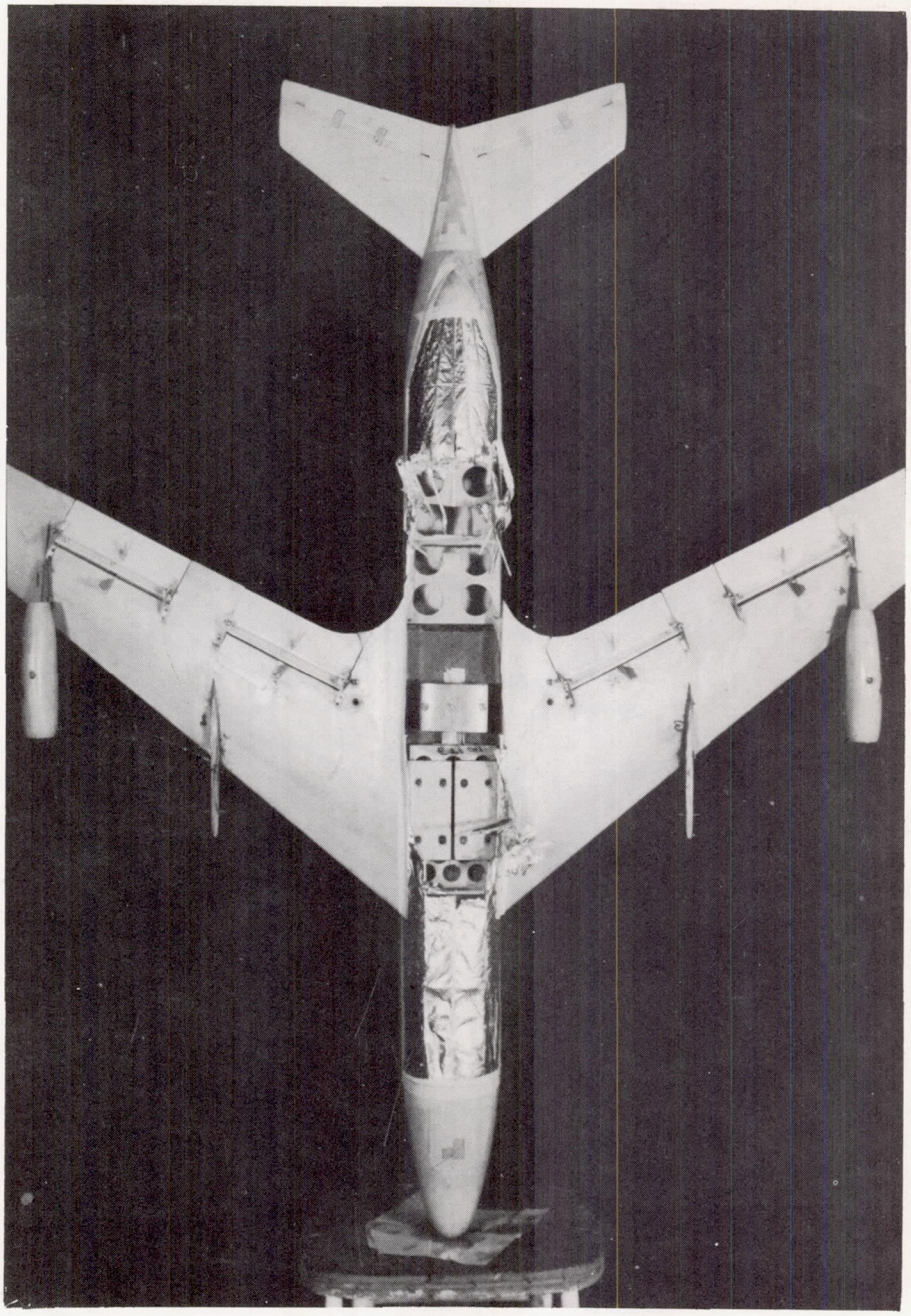
Figure 7.- Sequence photographs of a typical landing run with scale-strength fuselage bottom and scale-strength struts on the strut-pod engine installation. Flaps down: landing attitude, 12°; landing speed, 100 knots. Distance after contact is indicated in feet. All values are full scale.



L-90559

(a) Landing attitude, 12°; landing speed, 100 knots.

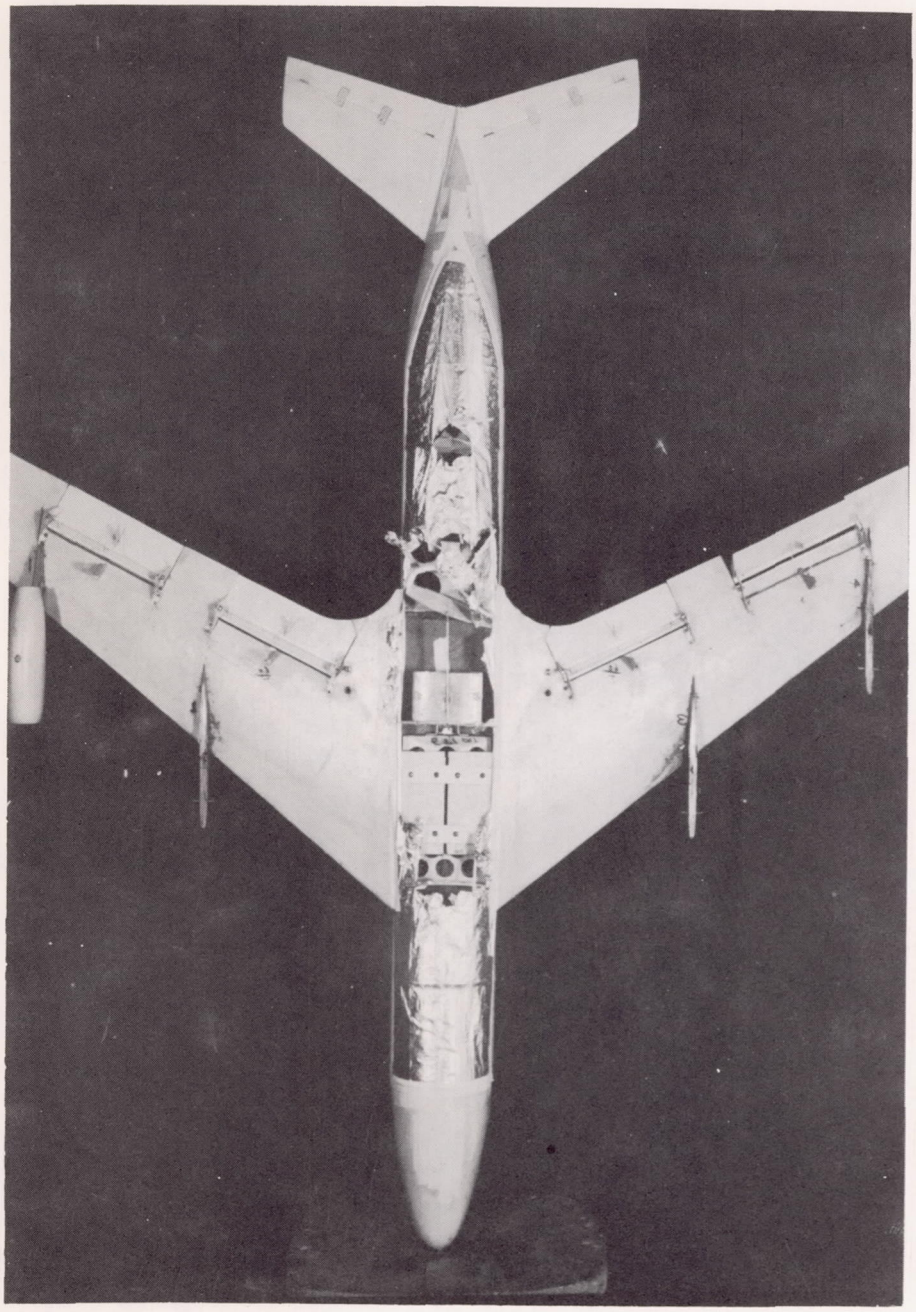
Figure 8.- Typical damage to the scale-strength bottoms. Flaps down.



L-90560

(b) Landing attitude, 9°; landing speed, 104 knots.

Figure 8.- Continued.



(c) Landing attitude, 6°; landing speed, 113 knots. L-90561

Figure 8.- Concluded.